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IUE OBSERVING PROGRAM

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Was 49: Mirror for a Hidden Seyfert 1 Galaxy

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Was 49: Mirror for a Hidden Seyfert 1 Galaxy

Final Technical Report

1. SUMMARY

Was 49 is an interacting pair of Seyfert galaxies at $z = 0.063$, one of which contains a hidden Seyfert 1 nucleus as evidenced by the highly polarized broad wings on its Balmer lines. The disk of the main galaxy, Was 49*a*, appears to be globally photoionized by a powerful continuum source, undoubtedly the hidden Seyfert 1 companion, Was 49*b*. The intrinsic luminosity of Was 49*b* is at least 100 times larger than the observed (scattered) luminosity.

We obtained a single SWP spectrum of the pair, which can be spatially resolved in the large aperture. A narrow Lyα line was detected from Was 49*b*, the hidden Seyfert 1, at a flux level consistent with that of an unreddened Seyfert 2 galaxy. The lack of detection of a continuum is consistent with a power-law of ν^{-1} or steeper extrapolated from the optical, again consistent with the spectrum of other Seyfert 2 and hidden Seyfert 1 galaxies.

2. INTRODUCTION

We recently found a double Seyfert galaxy system among the Wasilewski (1983) objective prism sample. Was 49 consists of a disk like galaxy at $z = 0.063$, plus a companion nucleus at a projected separation of $7''$ (13 kpc for $H_0 = 50$). The "main galaxy" is actually the *weaker* Seyfert, while the companion nucleus to the southwest has much stronger emission lines, but no detectable starlight (see Figure 1). The main galaxy is Was 49*a*, and the ususual companion to the southwest is Was 49*b*. Both objects are clearly Seyfert galaxies according to the standard emission-line ratio diagnostics. The detailed properties of Was 49 are described in a paper by Moran *et al.* (1992) which is reproduced in the Appendix. In addition to the rarity of double Seyfert systems, Was 49 is a wonderful laboratory for studying a "hidden Seyfert 1" for the following reasons:

1. Was 49*b* *is* a hidden Seyfert 1 galaxy, as evidenced by the weak broad wings on its Balmer lines. The continuum and the broad Balmer lines are highly polarized (Tran, Miller, & Kay 1992), consistent with electron scattering.
2. Seyfert-like emission lines are seen throughout the entire disk of Was 49*a*, indicating that it is photoionized by a source which is $\sim 100 - 300$ times stronger than is seen (by us) in the nuclear continuum of *either* galaxy. Was 49*b* is obviously this hidden source of global ionization.
3. A standard ionization parameter argument for the extended emission lines indicates that the *intrinsic* ionizing luminosity of Was 49*b* must be $\sim 1 \times 10^{45}$ ergs s^{-1}, rather like that of a quasar. Was 49 is also a "warm" IRAS source, with a far-infrared luminosity of 3×10^{44} ergs s^{-1} (Bothun *et al.* 1989), which could represent the fraction of the intrinsic luminosity that is reprocessed in the obscuring molecular gas.
4. It has long been known that a powerful quasar or Seyfert nucleus is capable of photoionizing the interstellar medium of a companion galaxy, which therefore acts as a "mirror" of the intrinsic properties of the nucleus, in this case, a hidden quasar in our

own cosmological back yard. The extended emission lines will enable the geometry and beaming factor of Was 49*b* to be determined.

5. Was 49*b* is a 20 mJy radio source, with at least 2 components that are roughly perpendicular to the position angle of optical polarization. The radio source is thus 4 times more luminous than 3C 71 (NGC 1068), the prototype hidden Seyfert 1 galaxy.

There is no question that Was 49*a* and *b* are dynamically associated. The emission-line rotation curve obtained in a long-slit spectrum covering both nuclei shows that Was 49*b* fits right onto the rotation curve of Was 49*a*, as though it were a test particle corotating with the disk. Indeed, the mystery of Was 49*b* is why it has no stellar system of its own, despite being by far the more powerful AGN.

3. Scientific Objectives

The Wasilewski (1983) sample consists of 95 emission lines discovered in a moderate-dispersion objective prism survey of an 825 sq. deg. region near the north galactic pole. The significance of this sample is that it selects galaxies by emission lines, rather than UV excess continuum as does the Markarian survey. So it is considered a truer indicator of the ratio of Seyfert 2 to Seyfert 1 galaxies. We made a comprehensive study of the Wasilewski sample of galaxies using IRAS data, CCD surface photometry, and spectroscopy (Bothun *et al.* 1989). The resulting classification of the 95 galaxies includes two Seyfert 1 galaxies, five Seyfert 2 galaxies, and Was 49, the subject of this proposal. So the ratio of Seyfert 2 to Seyfert 1 galaxies is roughly 3 to 1, depending on how you count Was 49. (The remaining Wasilewski galaxies have H II region spectra of one sort or another, and are not thought to be Seyferts.)

Was 49 is a uniquely interesting and complicated system. It hosts one of the few bona fide hidden Seyfert 1 galaxies as well as a companion Seyfert 2 galaxy. We are are studying it with many techniques from radio to X-ray, including narrow-band imaging, long-slit spectroscopy, and spectropolarimetry. Some results were reported by Moran *et*

al. (1992) and Tran *et al.* (1992). The required inputs for a complete model of the system are:

1. A knowlege of the ionizing spectrum, derived from emission line diagnostics and direct measurement of the scattered continuum at ionizing and near-ionizing wavelengths,
2. A picture of the geometry of the collimation and/or beaming from emission-line and radio maps, and
3. A determination of the dynamics of the stars and the emission-line gas using spatially resolved spectroscopy.

Although we have strong suspicions about the luminosities of ionizing sources in the system, there is as yet no direct detection of this ionizing continuum. Any continuum detected with IUE could be combined with optical and X-ray spectra (easily detectable by ROSAT), to determine a power-law continuum slope, or detect a UV bump, if any. Measurements of Lyα and C IV emission, in combination with the Balmer lines, will also constrain the shape of the ionizing continuum and the ionization parameter U in the nucleus of Was 49*b*.

Fortunately, we have good evidence that the reddening to the scattering region in Was 49*b* is small, since both the narrow-line and the broad-line components of the Balmer lines have the same ratio, H$\alpha/H\beta = 3.4 \pm 0.3$. This is close to the "case B prime" value of 3.1 which is derived for Seyfert galaxies when the contribution of collisional excitation to Hα is included in the photoionization models (Halpern and Steiner 1983; Ferland and Osterbrock 1985,1986). So this ratio reassures us that electron scattering, and not reddening, is responsible for the weak broad components of the Balmer lines.

4. OBSERVATIONS AND RESULTS

We requested a single shift to obtain one SWP exposure of Was 49. The date was chosen to obtain a specific aperture orientation parallel to the line between the two nuclei. Figure 1 shows the optimal placement of the galaxies in the aperture, with the nuclei symmetric about the center. The $7''$ separation of the nuclei perpendicular to the dispersion

direction is sufficient to allow them to be resolved in the extended line-by-line image. The observation on 1993 March 27 took place at a spacecraft roll angle of 5°. The resulting aperture orientation angle of 58° was close enough to the position angle of 63° between the nuclei.

Unfortunately, we were only able to obtain 250 minutes of exposure because the target was blocked by the Earth in the middle of the shift. The single exposure was obtained in two parts, with a gap of 137 minutes in between. In the resulting spectrum, only a narrow Lyα line was detected (see Figure 2) which was unresolved in the spectral and spatial directions. This is presumed to be from the nucleus of the hidden Seyfert 1, Was 49*b*. The Hβ flux of Was 49*b* is 2.4×10^{-14} ergs cm^{-2} s^{-1}. Since the Lyα/Hβ ratio is typically 5–15 in narrow-line Seyferts with unreddened Hα/Hβ (Ferland and Osterbrock 1986; Kinney *et al.* 1991; Rudy, Cohen and Puetter 1985) we expected a Lyα flux of $(1-4) \times 10^{-13}$. The observed flux was $\sim 1.7 \times 10^{-13}$, within the expected range.

It is more difficult to interpret the lack of a UV *continuum*, since the optical continuum in Was 49*b* is of uncertain origin, and its slope is not well measured. If the flux of $\sim 2 \times 10^{-27}$ ergs cm^{-2} s^{-1} Hz^{-1} at 5000 Å is extrapolated to 1500 Å with a slope of -1.0, then a flux of $\sim 1 \times 10^{-15}$ ergs cm^{-2} s^{-1} Å^{-1} will expected. Any contribution due to a UV bump can increase the flux significantly. Since the observed upper limit to the continuum flux is of order $\sim 1 \times 10^{-15}$, we can only say that the optical/UV spectrum is steeper than ν^{-1}, which is not a very restrictive limit.

The Balmer emission lines of Was 49*a* are approximately 15 times weaker than that of Was 49*b*. Therefore, it is not surprising that Lyα was not detected in Was 49*a*. The flux limit is $\sim 3 \times 10^{-14}$ ergs cm^{-2} s^{-1} for a narrow Lyα line, and the expected flux from Was 49*a* is only $\sim 1 \times 10^{-14}$. All the results of this IUE observation are then consistent with the theory that Was 49*b* is a hidden Seyfert 1 nucleus which is responsible for the ionization of the outer disk of its companion Seyfert 2 galaxy, Was 49*a*

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FIGURE CAPTIONS

FIG. 1. – CCD image of Was 49 in the R band. The system consists of a disk-like Seyfert galaxy, Was 49a, plus an almost "bare" companion Seyfert nucleus, Was 49b, 7$''$ to the southwest. The SWP large aperture was oriented at a position angle of 58°, which is nearly parallel to the line between the two nuclei. The two nuclei were placed symmetrically about the center of the aperture.

FIG. 2. – SWP spectrum of Was 49, showing the detection of Lyα in the nucleus of Was 49b at the redshift of 0.063. The line flux is $\sim 1.7 \times 10^{-13}$ ergs cm^{-2} s^{-1}.

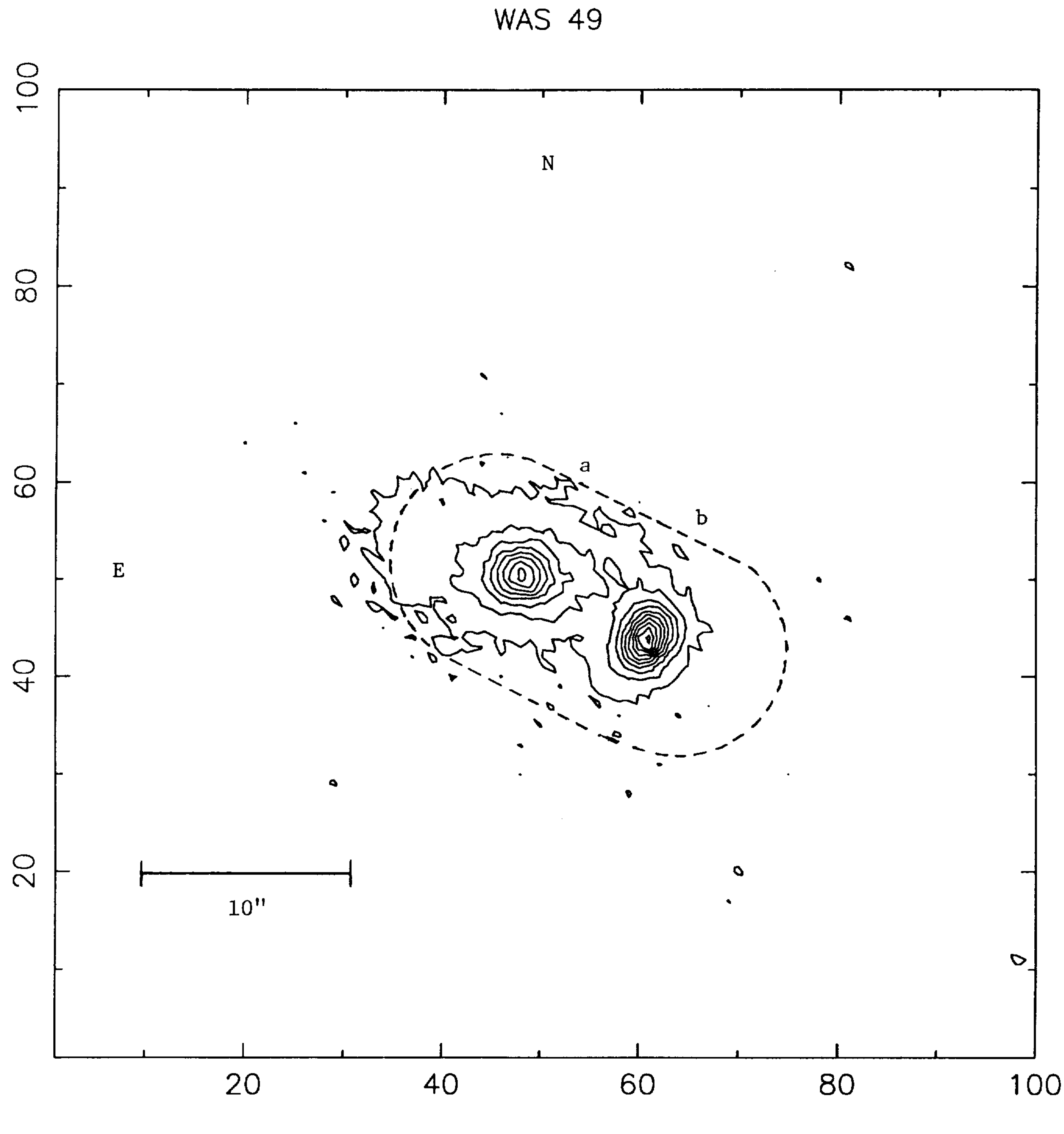

Figure 1

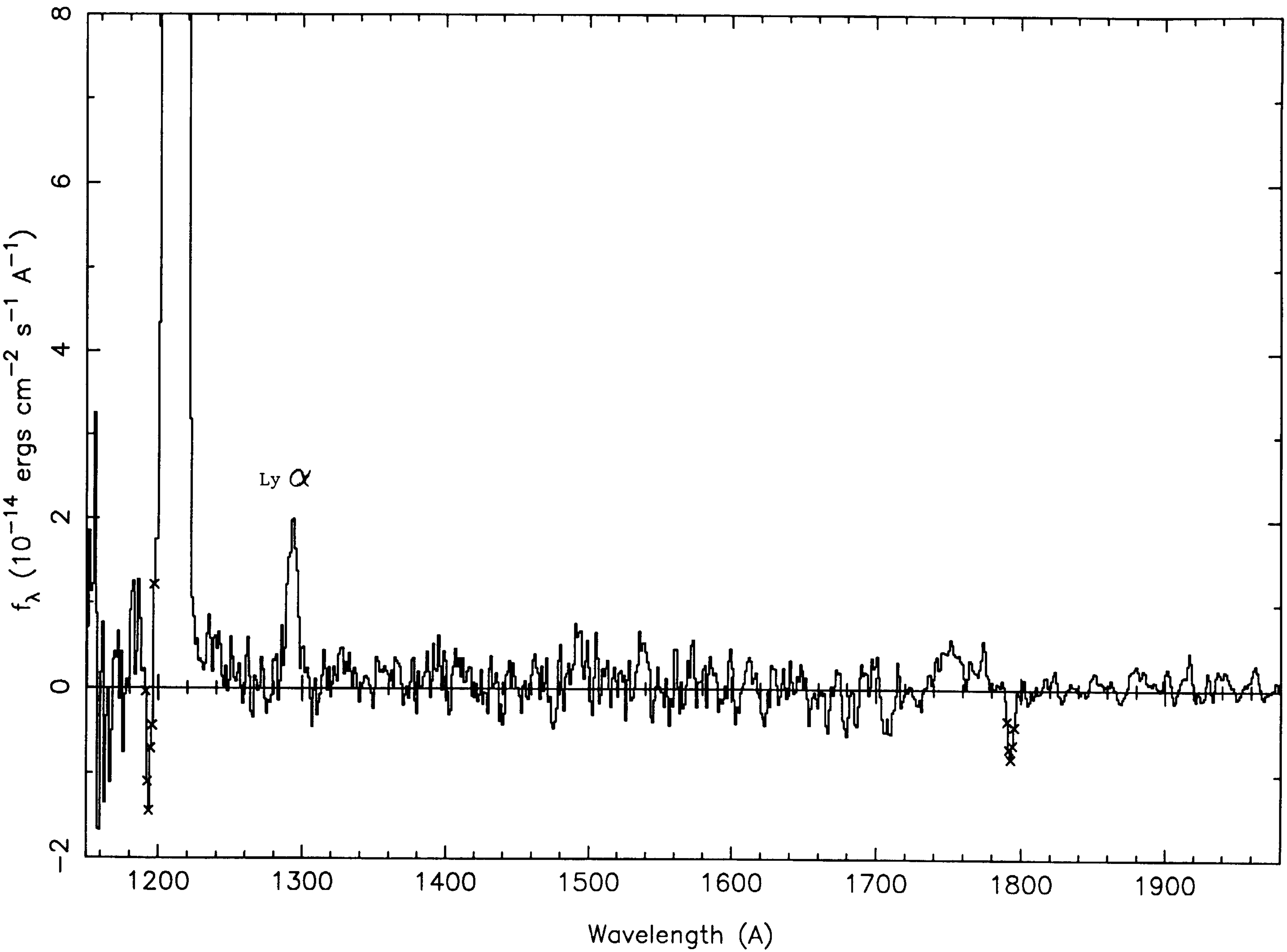
8
6
4
2
0
−2
f_λ (10^{-14} ergs cm^{-2} s^{-1} A^{-1})
Ly α
1200
1300
1400
1500
1600
1700
1800
1900
Wavelength (A)

Figure 2

APPENDIX

Papers Published Under NASA Grant NAG 5-2092

"Was 49: Mirror for a Hidden Seyfert 1 Nucleus," E. C. Moran, J. P. Halpern, G. D. Bothun, & R. H. Becker, *A. J.*, **104**, 990 (1992).

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